

WHAT IS CLAIMED IS:

1. A metal article comprising:
 - a plurality of metal particles;
 - a metal or metalloid binder material disposed to form a transient liquid phase at a treatment temperature below the temperature of joining of said metal particles, below the temperature of formation of substantial amounts of a ductile alloy of said metal of said metal particles and said binder material and above the temperature of formation of at least one intermetallic compound of said metal of said metal particles and said binder material, said metal particles and said binder material being compacted to the shape of said metal article, then heated to said treatment temperature for a time sufficient to form said transient liquid phase and at least one intermetallic compound, and then cooled to form said metal article.
2. A frangible metal article comprising:
 - a plurality of metal particles;
 - a brittle binder for joining said metal particles, said binder consisting essentially of at least one intermetallic compound.
3. The frangible metal article of claim 2 wherein said metal particles and a metal or metalloid binder material are compacted to the shape of a bullet, then heated to said treatment temperature for a time sufficient to form an effective amount of said transient liquid phase and at least one intermetallic compound, and then cooled to form said frangible metal bullet.

4. The frangible metal article of claim 2 wherein said metal particles consist essentially of metals or metal-base alloys selected from the group consisting of copper, iron, nickel, gold, silver, lead, chromium and their alloys.

5. The frangible metal article of claim 2 wherein said metal or metalloid binder material consists essentially of a material selected from the group consisting of: tin, zinc, gallium, germanium, silicon, arsenic, aluminum, indium, antimony, lead, bismuth, their mixtures and their alloys.

6. The frangible metal article of claim 2 wherein said binder consists essentially of at least one intermetallic compound of a first metal selected from the group consisting of copper, iron, nickel, gold, silver, lead, chromium and a second metal or metalloid selected from the group consisting of: tin, zinc, gallium, germanium, silicon, arsenic, aluminum, indium, antimony, lead, bismuth.

7. A frangible, lead-free, metal bullet comprising:

 a plurality of metal particles, said metal being selected from the group consisting of: copper, iron, nickel and chromium;

 a metal or metalloid binder material disposed to form a transient liquid phase and a brittle metal binder comprised of at least one intermetallic compound at a treatment temperature below the temperature of metal particle to metal particle bonding or the formation of significant quantities of a binder/metal particle alloy.

8. The frangible metal bullet claim 7 wherein said metal particles and said binder material are compacted to the shape of said bullet, then heated to said

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treatment temperature for a time sufficient to form said transient liquid phase, at least one intermetallic compound and then cooled to form said metal bullet.

9. The frangible metal bullet of claim 7 wherein said metal particles consist essentially of copper or copper-base alloys.

10. The frangible metal bullet of claim 9 wherein said binder consists essentially of tin or tin-based alloys.

11. The frangible metal bullet of claim 9 wherein said binder material consists essentially of tin and said brittle binder comprises an intermetallic compound of copper and tin.

12. The frangible metal bullet of claim 11 wherein said intermetallic compound of copper and tin consists essentially of the eta phase.

13. A frangible metal bullet comprising:

 a plurality of unsintered metal particles;
 an intermetallic compound binder joining said metal particles to form said metal bullet.

14. The frangible metal bullet of claim 13 wherein said binder has a microstructure characterized as a porous, brittle, re-solidified transient liquid phase that has formed at least one intermetallic compound and bonded to the adjoining metal particles.

15. The frangible metal bullet of claim 13 wherein said metal bullet consists of a material having a transverse rupture strength of less than 13,000 psi.

16. The frangible metal bullet of claim 13 wherein said frangible metal bullet is rendered into a plurality of particles by brittle failure of said binder.

17. The frangible metal bullet of claim 16 wherein the fracture of said frangible metal bullet into a plurality of particles absorbs the majority of the kinetic energy of said bullet.

18. A method of making a metal article, said method comprising the steps of:
forming a mixture comprising metal particles and a metal or metalloid binder material, said metal binder material being disposed to form a transient liquid phase and at least one intermetallic compound at a treatment temperature below the temperature of joining of said metal particles and below the temperature of formation of substantial amounts of a ductile alloy of said metal particles and said binder;
compacting said mixture to form a shaped green compact;
heating said shaped green compact to said treatment temperature for a time sufficient to form an effective amount of a transient liquid phase of said binder and at least one intermetallic compound, thereby forming a shaped metal precursor; and
returning said shaped metal precursor to room temperature to form said metal article.

19. The method of making a frangible metal article set out in claim 18, wherein the dimensions of said shaped green compact are within 0.2 % of the dimensions of said frangible metal article.

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20. A method of making a frangible metal bullet, said method comprising the steps of:

forming a mixture comprising metal particles and a metal or metalloid binder material disposed to form a transient liquid phase and at least one intermetallic compound at a treatment temperature below the temperature for joining said metal particles and formation of substantial amounts of a ductile alloy of said metal particles and said binder material;

compacting said mixture to form a green compact in the shape of said bullet;

heating said green compact to said treatment temperature for a time sufficient to form an effective amount of a transient liquid phase of said binder material and at least one intermetallic compound, thereby forming a shaped metal precursor; and

returning said metal precursor to room temperature to form said frangible metal bullet.

21. The method of making a frangible metal bullet as set out in claim 20, wherein said metal particles consist essentially of copper, and said binder material consists essentially of tin and said green compact is heated to a temperature in the range of from 230 to 700°C for up to sixty minutes.

22. The method of claim 21, wherein said green compact is heated to a temperature in the range of from 230 to 430°C for up to sixty minutes.

23. The method of making a frangible metal bullet as set out in claim 20, wherein the dimensions of said green compact are within 0.2% of the dimensions of said frangible metal bullet.

24. A lead-free cartridge comprising:

a cartridge case having a neck;

a lead-free primer composition;

propellant within said case; and

5 a frangible, lead-free, metal bullet comprised of a plurality of unsintered metal particles joined with a brittle binder consisting essentially of at least one intermetallic compound, said metal particles comprising a metal selected from the group consisting of copper, iron, nickel, chromium, tungsten and their alloys, said bullet being in said case neck.

25. The cartridge of claim 24 wherein said binder material comprises a material selected from the group consisting of: tin, zinc, gallium, germanium, silicon, arsenic, indium, aluminum, antimony, bismuth and their mixtures.

26. The cartridge of claim 24 wherein said cartridge is a centerfire cartridge having a primer pocket with a primer therein.

27. The cartridge of claim 24 wherein said cartridge is a rimfire cartridge.

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